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AD-A223 744

## CABLE SPLICING TECHNOLOGY

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JUL 10 1988  
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*Final Report prepared for Office of Naval Research Contract  
N00014-85-K-0800 for the Period 08-15-85 - 08-14-87.*

MPL-U-16/89  
March 1989

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90 07 9 099

1a. REPORT SECURITY CLASSIFICATION <b>UNCLASSIFIED</b>		1b. RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE			
4. PERFORMING ORGANIZATION REPORT NUMBER(S)  MPL-U-16/89		5. MONITORING ORGANIZATION REPORT NUMBER(S)	
6a. NAME OF PERFORMING ORGANIZATION  Marine Physical Laboratory	6b. OFFICE SYMBOL (If applicable) MPL	7a. NAME OF MONITORING ORGANIZATION  Office of Naval Research Department of the Navy	
8c. ADDRESS (City, State, and ZIP Code) University of California, San Diego Scripps Institution of Oceanography San Diego, CA 92152		7b. ADDRESS (City, State, and ZIP Code) 800 North Quincy Street Arlington, VA 22217-5000	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Office of Naval Research	8b. OFFICE SYMBOL (If applicable) ONR	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00014-85-K-0800	
8c. ADDRESS (City, State, and ZIP Code) Department of the Navy 800 North Quincy Street Arlington, VA 22217-5000		10. SOURCE OF FUNDING NUMBERS	
		PROGRAM ELEMENT NO.	PROJECT NO.
		TASK NO.	WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification)  Cable Splicing Technology - Final Report for ONR Contract N00014-85-K-0800			
12. PERSONAL AUTHOR(S) F. N. Spiess, Principal Investigator			
13a. TYPE OF REPORT Final Report	13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Year, Month, Day) March 1989	15. PAGE COUNT 5
16. SUPPLEMENTARY NOTATION			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)  electromechanical cables, cable splicing, Energy Conversion Wire Inspection and Repair, Oceanography	
19. ABSTRACT (Continue on reverse if necessary and identify by block number)  Over the last two decades an increasing number of 0.68" diameter coax core electromechanical cables have been used in deep sea oceanographic work. As these have aged, or sustained localized damage, there has been corresponding growing concern over the possibility of locating mechanical defects and of cutting out bad sections and splicing the remaining good sections together in useable lengths. First attempts at salvaging a relatively new wire that had sustained local damage was done in 1982. In this case there was a localized failure in the coax core. We cut out the short damaged section and, with assistance from Vector cable company employees who had substantial oil field experience, made a splice that was used, but with need for substantial tending after each pass through the sheave and traction unit system.			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS		21. ABSTRACT SECURITY CLASSIFICATION <b>UNCLASSIFIED</b>	
22a. NAME OF RESPONSIBLE INDIVIDUAL Fred N. Spiess		22b. TELEPHONE (Include Area Code) (619) 534-1621	22c. OFFICE SYMBOL MPL

## **CABLE SPLICING TECHNOLOGY**

### **Splicing of 0.68" Electro-Mechanical Cable**

**Fred N. Spiess, Principal Investigator**

*Final Report prepared for Office of Naval Research Contract  
N00014-85-K-0800 for the Period 08-15-85 - 08-14-87.*

#### **I. Introduction**

The material below documents the work carried out under contract N00014-85-K-0800. It constitutes a part of a longer paper on wire inspection and repair being prepared for submission to the Journal of the Marine Technology Society.

Over the last two decades an increasing number of 0.68" diameter coax core electromechanical cables have been used in deep sea oceanographic work. As these have aged, or sustained localized damage, there has been corresponding growing concern over the possibility of locating mechanical defects and of cutting out bad sections and splicing the remaining good sections together in useable lengths.

Our group's first attempt at salvaging a relatively new wire that had sustained local damage was in 1982. In this case there was a localized failure in the coax core. We cut out the short damaged section and, with assistance from Vector cable company employees who had substantial oil field experience, made a splice that was used, but with need for substantial tending after each pass through the sheave and traction unit system.

With these and a number of other similar experiences behind us, we searched for an opportunity to test, under controlled conditions, our splicing methods. This possibility materialized during the 1985-88 time frame, with support from the Office of Naval Research under this contract.

## II. Splicing.

The basic approach to splicing this type of wire is dictated by the geometry of the wire itself. Since the individual strands make up two separate layers, and the individual wires are not woven or twisted together in any way, it is necessary to make a long splice in order that the load can be re-distributed among the adjacent strands. At the same time the relatively small number of component wires and their well controlled geometry make it easy to carry out the splicing process in an orderly manner.

The basic procedure developed for making a splice of length  $L$  starts by unlaying the outer layer of end A back by approximately the distance  $L$ , coiling up the strands and being careful not to kink them. Next unlay the inner strands of end A to about  $1/2 L$  and cut them off. Then continue unlaying them back as far as the outer lay was unlaid. Cut off the exposed length of end A coax core leaving about two meters available for making the electrical splice. On the B end, unlay the outer layer to a distance of about  $1/2 L$  and cut off the unlaid material on that end.

Remove and cut off 3 m. of inner armor from end B to expose the conducting core and splice the two ends of coax together. This splice must be carefully made in order to preserve internal insulation properties, be waterproof and not produce a bulge in the wire. Particularly if the cable is to be used subsequently for transfer of power at high voltage, the cable should then be tested to demonstrate that the splice will not break down when full voltage is applied.

Strands from the inner layer of end A are then laid, one at time, back over the electrical splice and into the area of end B, where its inner lay is exposed. Each individual strand from A is laid in to replace a portion of a corresponding strand of end B, which is simultaneously unlaid. Both are then cut off and seated between the adjacent strands. Once all the inner lay strands from A are meshed with B, the outer strands from A are re-layed to cover the inner layer spliced zone. The individual A strands are then laid into the outer layer of end B in similar manner, with removal of appropriate lengths of corresponding B strands. The butt joints are successively secured and the

splice is complete.

The parameters available to the splicer are thus the total length of the splice, the pattern in which the individual strands are meshed together, and the means for securing the loose ends at the butt joints on the outer layer. In our initial try, guided by oil field experience, we terminated adjacent strands at successive intervals about two feet apart, thus the total length of the splice was about two feet times the total number of strands. After using this configuration at sea we decided that a more conservative approach, using one meter steps, would be preferable. More important, however, we recognized that if one butt joint came apart and the strand caught in the sequence of sheaves and guides, the adjacent joint, only 2 feet away, was immediately left unsupported on one side and was likely to fail as well. This zipper opening possibility seemed quite risky and led us to use a different splicing geometry.

The cable used in our test operation had 30 strands in the outer layer and 24 in the inner layer. We chose to use a one meter unit for the splice, thus making it approximately 55 m long overall (including the electrical splice). For ease of handling, we unlaid the outer armor in 6 groups of 5 adjacent strands and the inner armor in 6 groups of 4 adjacent strands.

When laying the internal end A strands into end B (with removal of corresponding B strands) the first of the 4 wires was terminated at the beginning of the inner lay of end B, the second 12 m from that point, the third at 6 m and the fourth at 18 m. The next group of four strands was laid in similarly, but starting with a reference point a meter further along the wire. Subsequent groups repeated the sequence, each with a one meter additional step along the wire.

The outer layer strands from end A were then laid over the inner armor splice and meshed with the outer layer of B with a pattern in each group of 0, 18, 6, 24, 12 m lengths, stepped along 1 m for each group. In this arrangement the shortest distance between joints in adjacent wires is 11 m, thus allowing a substantial distance for friction between adjacent strands to distribute the load.

A variety of means have been tried to restrain the ends of the butt joints in the outer layer. The first we saw was that used by the oil field men who worked with us on our first splice. Their approach was to braze the two ends together and braze them to the two adjacent strands. While this presumably was a successful approach in the oil field context of very few sheaves in the line, in our case, with the wraps around the traction unit and the various guide and accumulator sheaves on deck, we found that the stiff zone associated with the brazing would crack, not only releasing the wire ends that had been joined, but often breaking the adjacent strand as well. This approach was thus rejected after our initial experience.

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We have tried two other approaches under a variety of circumstances in which either a few broken strands needed to be retained or a full splice was made. The first of these involved use of thin stainless steel sleeves into which the two free ends were inserted. In the second approach a piece of shim stock is slipped under the adjacent 2 or 3 strands, looped over the butt joint and slipped back under the stands on the other side. In some situations it is best to use two pieces, one to hold down each of the two strands that are butting against one another. Our experience with these two approaches had been positive; however, we had not had an opportunity to compare them with one another, with the chance of using several different combinations of material and shim thickness. This controlled test program provided that opportunity.

### **III. Test Facility and Procedure**

The test facility used in this program was built at the Marine Physical Laboratory during 1986/87 using funds provided by the Department of Defense Instrumentation Program. It consists of a horizontal L-shaped layout with a driven sheave at one end, a pair of sheaves at the corner and a single sheave at the far end. Inserted into the path is a set of five sheaves, mounted vertically, three on fixed axes and two supported by a crosshead held up by two hydraulic cylinders. A closed loop of wire traversing these nine sheaves was formed by the splicing process and desired tension was obtained by applying pressure to the hydraulic cylinders. Total length of the wire loop was 136 m.

The splice to create the test loop was made as described above, with the goal of determining its durability. Since there were thirty outer strands this provided an opportunity to compare various materials for holding the ends of the strands in place. Seven of the joints were secured with stainless steel tubing 0.059" ID, 0.069" OD and 2.25" long. The remaining 23 joints were held by pairs of shim stock inserts of various thicknesses. Some were of stainless steel and some of brass, as shown in Table 1.

The test loop was initially run at 1,000 lbs. tension continuously in one direction. It became apparent that there was some small motion of the hold-down shims during each pass, with the result that unidirection cycling would soon lead to their walking away from the joints they were designed to hold down. Since at-sea operation would not normally involve passes in one direction over more than perhaps 15 sheaves (including the winch traction unit and a slack tensioner) it was decided that reversing direction after each pass (9 sheaves) would be the most straightforward procedure.

A convenient tension of 6,000 lbs. was then applied and the splice was run through 100 more cycles for a total of 105. Through all this process no major slippage of the splice occurred; however, the means for holding down a number of the outer strands showed failures after various numbers of cycles.

The first to fail were the stainless steel tubing hold-downs. All but one of these had to be replaced with shim stock by the end of the 45th pass through the 9 sheave system. Next most fragile were the .003" stainless steel shims, one of the eight failing on lap 36 and one other on lap 48. None of the .005" nor .007" stainless failed, although several of them slipped along the wire and had to be moved back into place. One of the brass shims failed on lap 101.

The electrical splice was still in good condition when the wire was dissected after the operation was completed. Inspection of the inner layer of strands showed that the original gaps of 2-3 mm had opened to 1 to 1.5 cm - the best indication of the amount of extension experienced during the 105 laps.

#### IV. Conclusions

Long splices of 0.68" electromechanical cable can be made successfully and will perform durably over many cycles. Preferred materials for securing outer strand ends are brass or stainless steel shim stock of 0.005" to 0.010" thickness. Careful inspection of the splice during each major passage of the wire through the handling system is essential. If this is done, then migration of securing shims along the wire can be corrected. The splice should be refurbished at low tension after about every 500 sheave passages, replacing any broken hold-downs. If the wire is used with a traction winch this refurbishing can be done on the low tension side between the traction unit and storage drum in connection with the inspection after each use.

Use of spliced wires, although in principle a practical approach, introduces some operational constraints. In particular one would not want to operate under circumstances in which frequent repeated passes of the splice through the sheave system were necessary. Such situations could occur, for example, when towing a vehicle close to the sea floor having irregular low relief. In such cases it may not be possible to use a wide enough range of speeds to change the section moving back and forth through the sheave system. This condition is aggravated by the fact that wire may have to be wound in quickly at unpredictable times in response to abrupt rises in topography, thus

precluding being able to stop winding to secure a strand that has come loose. This implies that under many conditions, if there is a choice, the wire should be spooled in such a way that the splice is closer to the outboard end of the wire than inboard. Thus it can go into or out of the sheave system while the payload is well up in the water column.

The work of D. E. Boegeman, G. Austin and R. Bernhardt, as well as of Marine Physical Laboratory shop personnel under direction of W. Davy, is gratefully acknowledged.

**TABLE 1****Means for Holding Free Ends of Spliced Strands**

Material	Strand number
.059" ID, .069" OD, 2.25" long 55 tubing	0, 1, 6, 7, 12, 18, 24
.003" SS sheet, .75' wide, 3" long	2, 8, 13, 14, 19, 20, 25, 26
.005" SS sheet, .75" x 3"	3, 9, 15, 21, 27
.007' SS sheet, .75' x 3"	4, 10, 16, 22, 28
.010' brass sheet, .75" x 3"	5, 11, 17, 23, 29